

Proton Charge Radius Measurement - PRad-II Experiment : Progress of Data-taking and Preliminary Analysis



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Proton Charge Radius

- Proton is a basic component of the universe
- The root-mean-square charge radius (r_p) is a critical properties of proton
- Input to QED calculations of atomic hydrogen, important to test QCD calculations

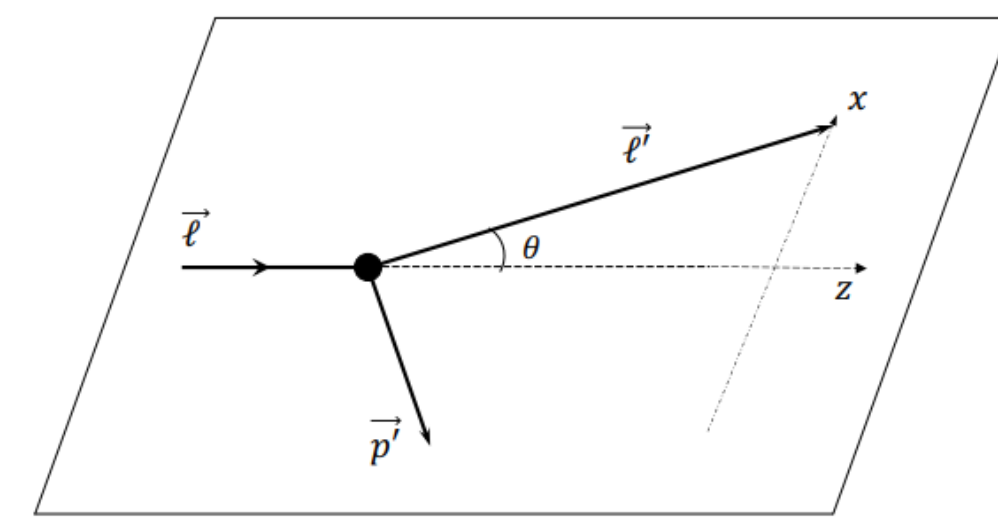


Two Experimental Method to Measure r_p

- Lepton-proton elastic scattering

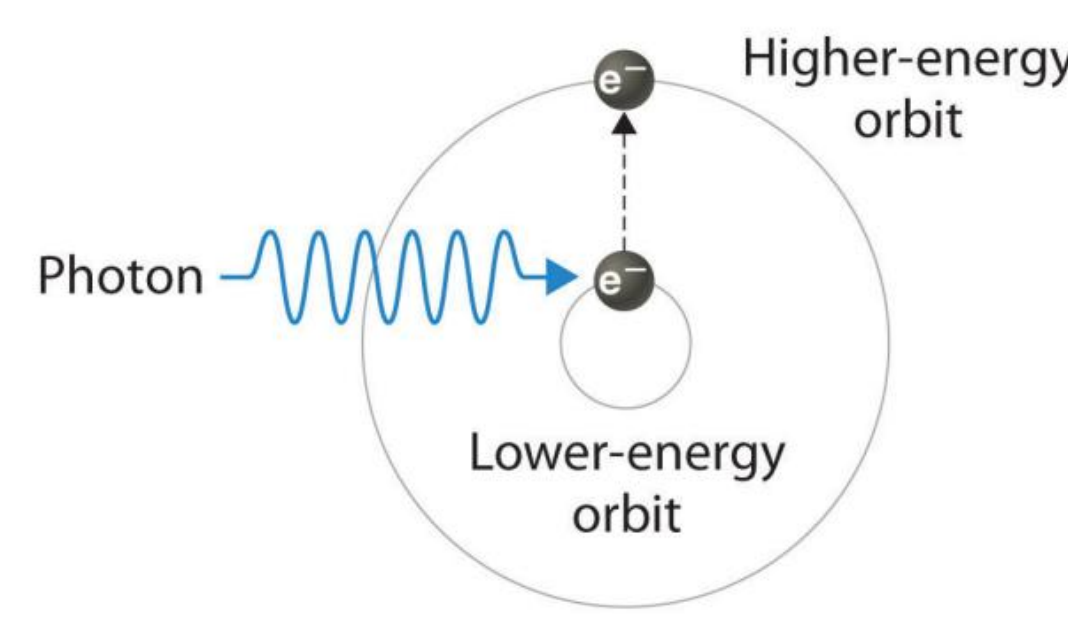
- Elastic cross section measurement to extract G_E^p

$$\overline{r_p^2} \equiv -6 \left. \frac{dG_E^p(Q^2)}{dQ^2} \right|_{Q^2=0}$$



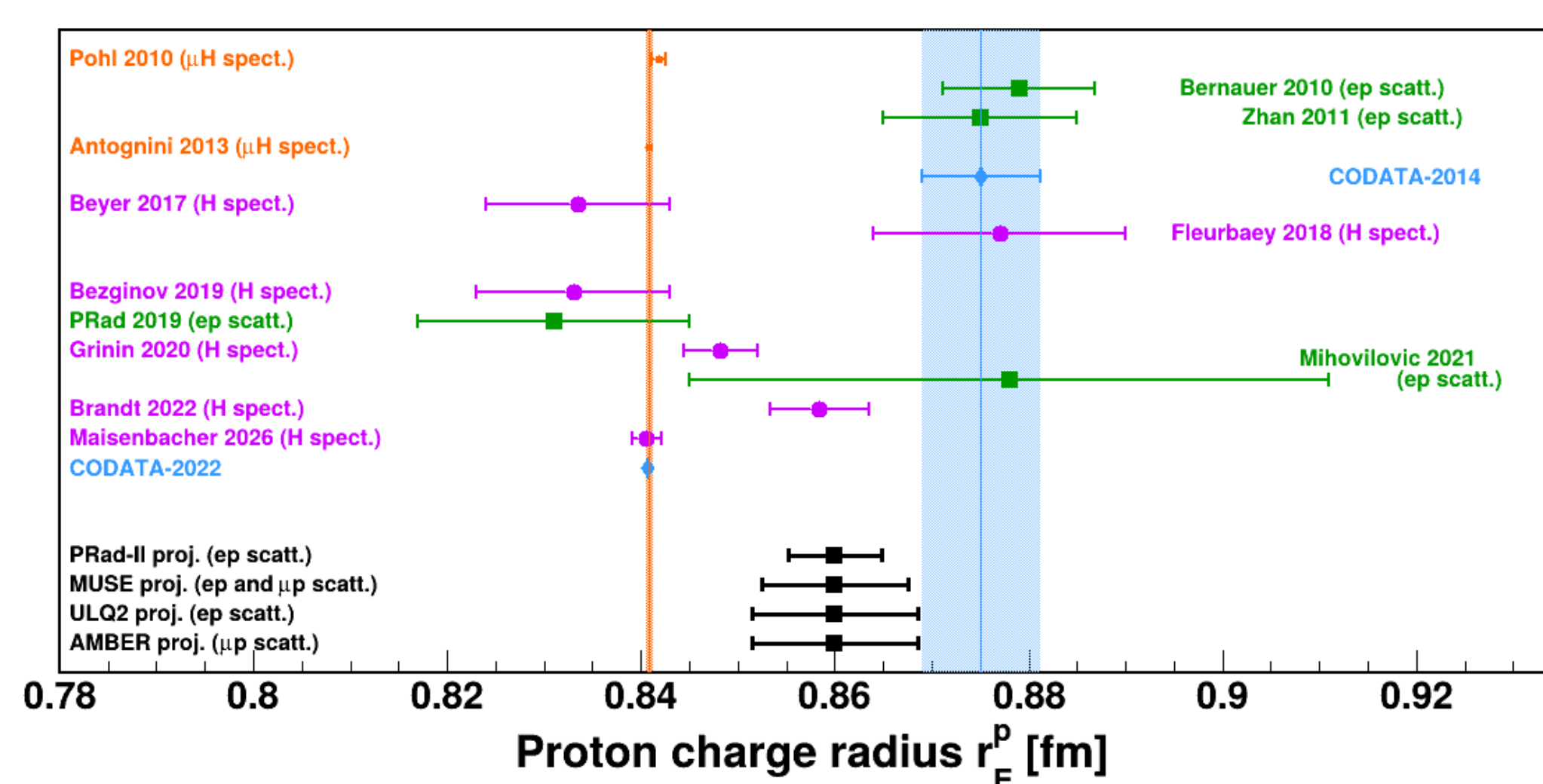
- Hydrogen spectroscopy

- Determine the r_p by measuring Lamb shift
- Muonic hydrogen (μH) is more sensitive to proton size



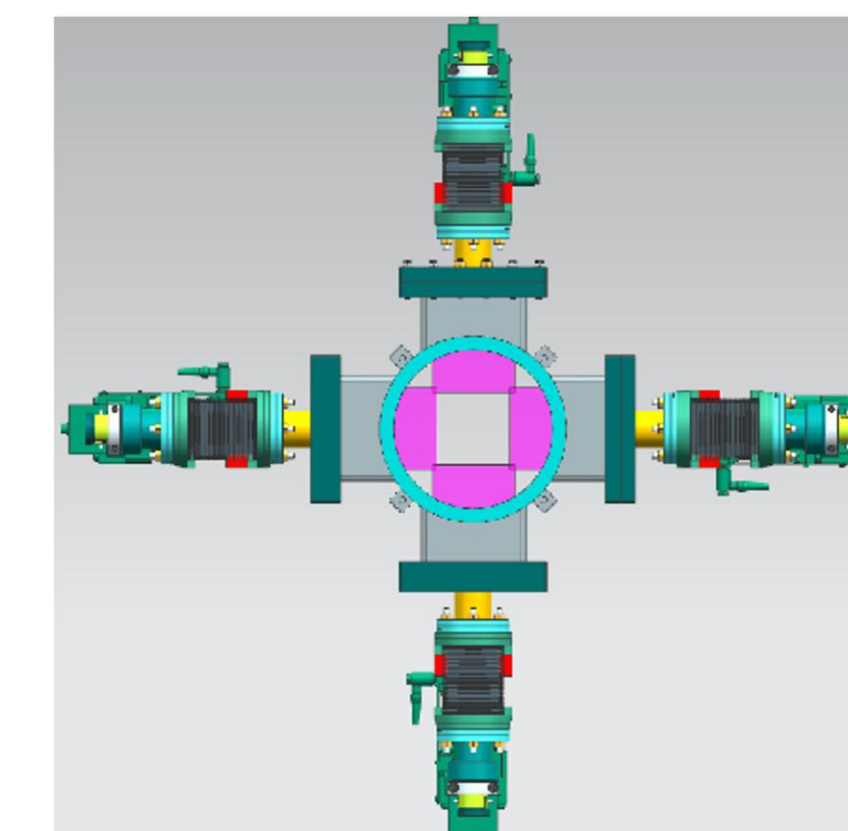
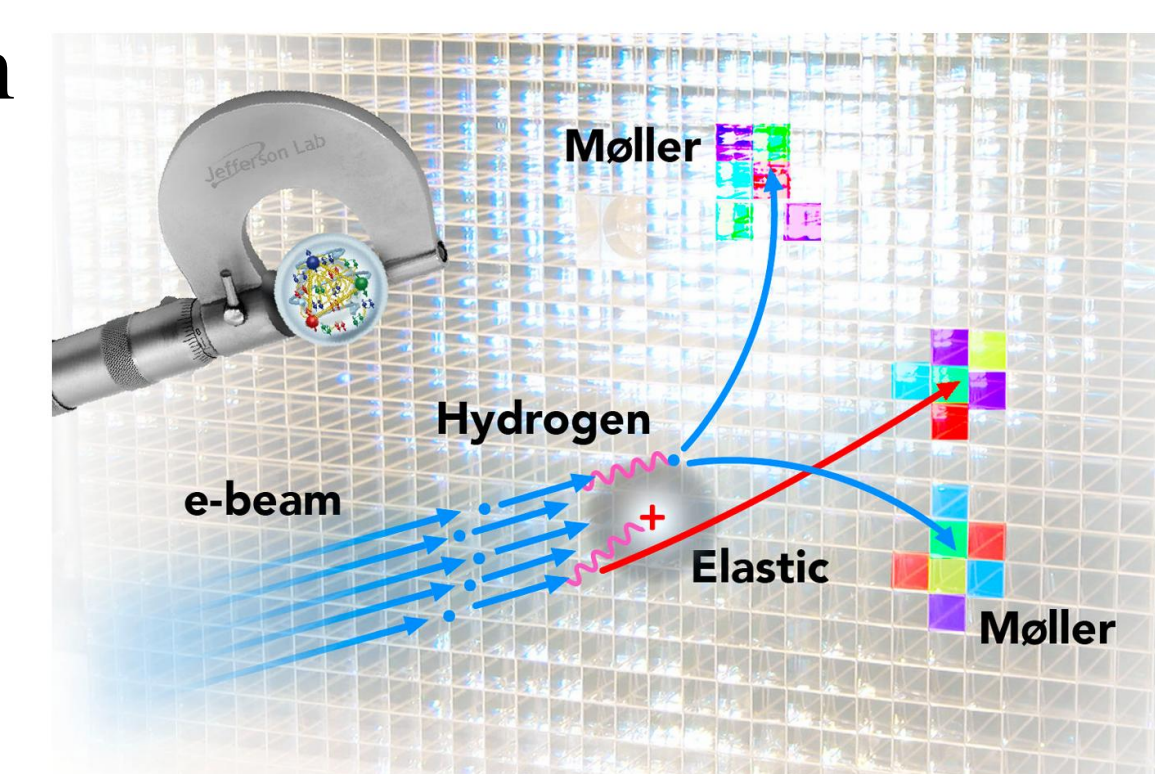
Radius Puzzle and PRad Experiment

- r_p result from the μH spectroscopy is 4.5% smaller than previous result and it has the best precision ($\sim 0.05\%$)
- PRad experiment, performed at JLab in 2016, published in 2019 at Nature, 1st e-p scattering experiment that agreed with μH spectroscopy results
- The upgraded new PRad-II experiment is aiming ~ 3.5 times improvement on precision compared with PRad



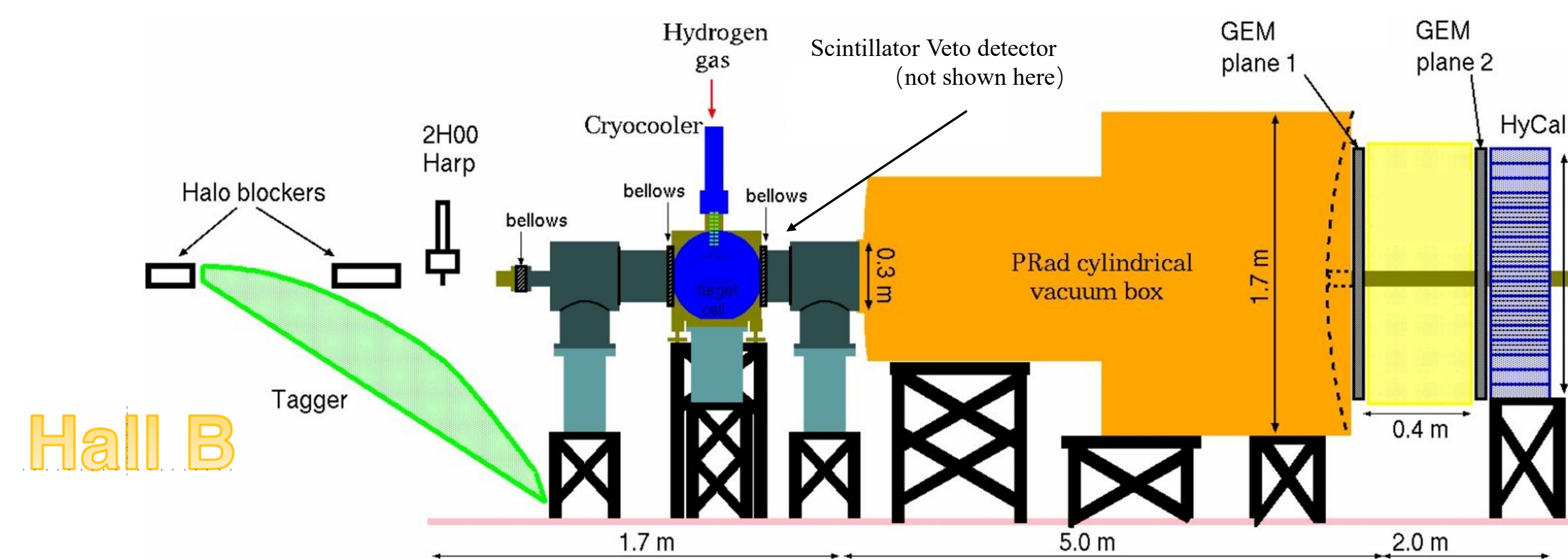
PRad-II Experiment

- High precision elastic electron-proton scattering measurement at extremely low four momentum transfer (Q^2)
- Novel magnetic-spectrometer-free apparatus, the Hybrid Calorimeter (HyCal) and Gas Electron Multiplier (GEM) as main detectors
 - Small angles & Q^2 , minimize G_M^p contribution
 - Simultaneously measure e-p & e-e to control systematics uncertainty
 - Windowless H2 gas flow target to suppress background



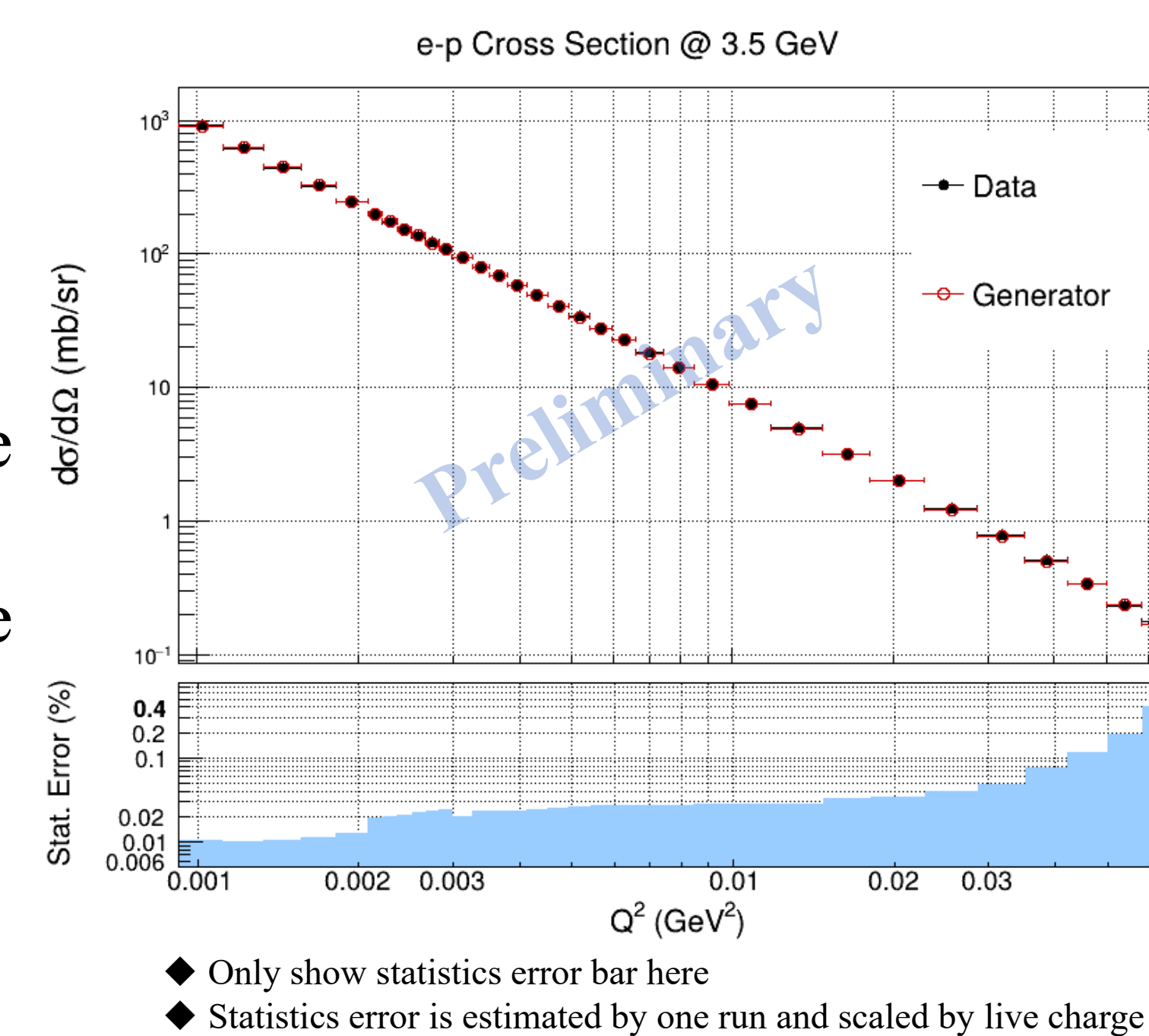
- Upgraded from PRad:

- Extra new GEM plane for better tracking and efficiency measurement
- FADC based readout for HyCal
- New veto detector help reach the smallest $Q^2 \sim 5 \times 10^{-5} \text{ GeV}^2$
- New NNLO radiative correction



Current Status of Data Taking

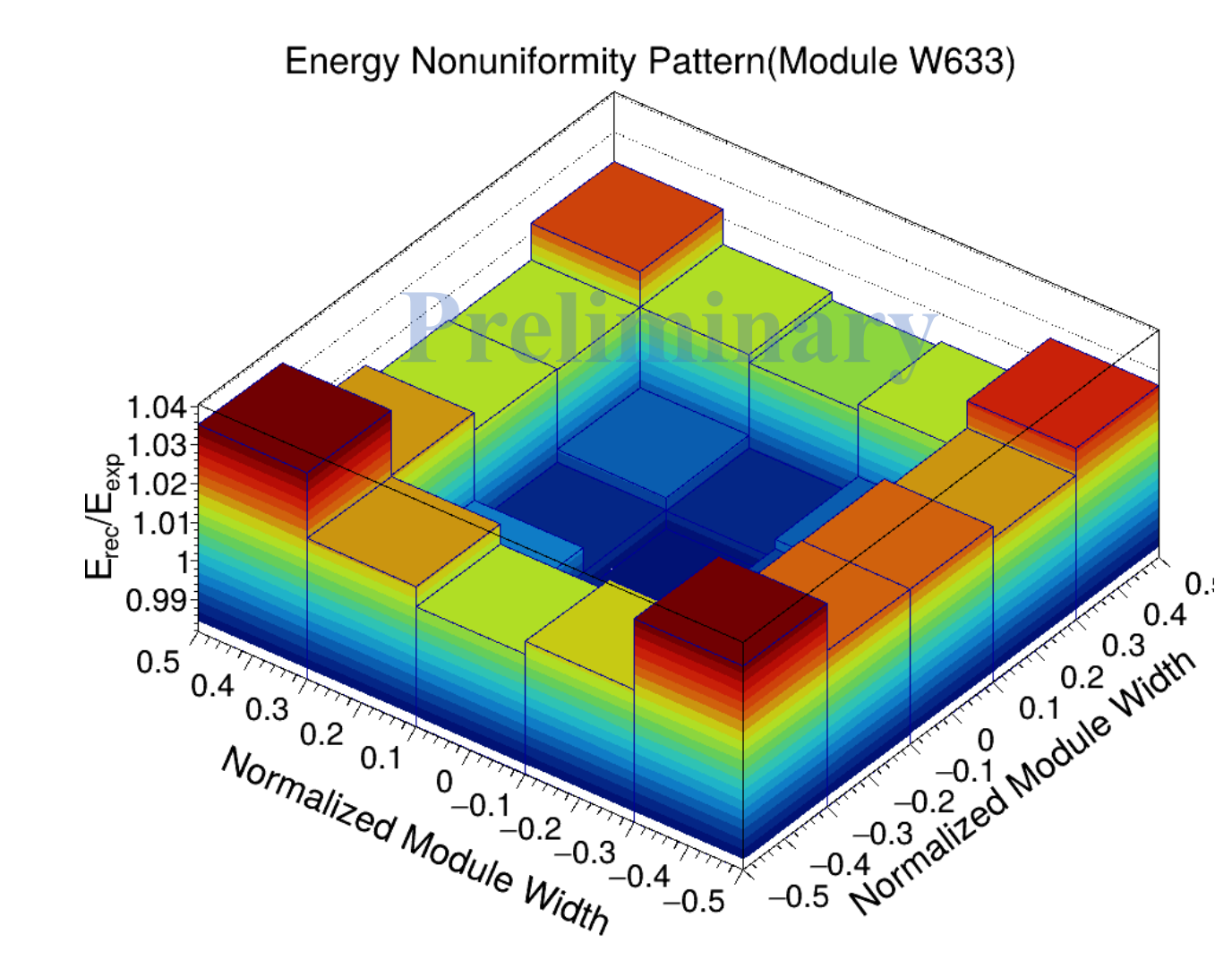
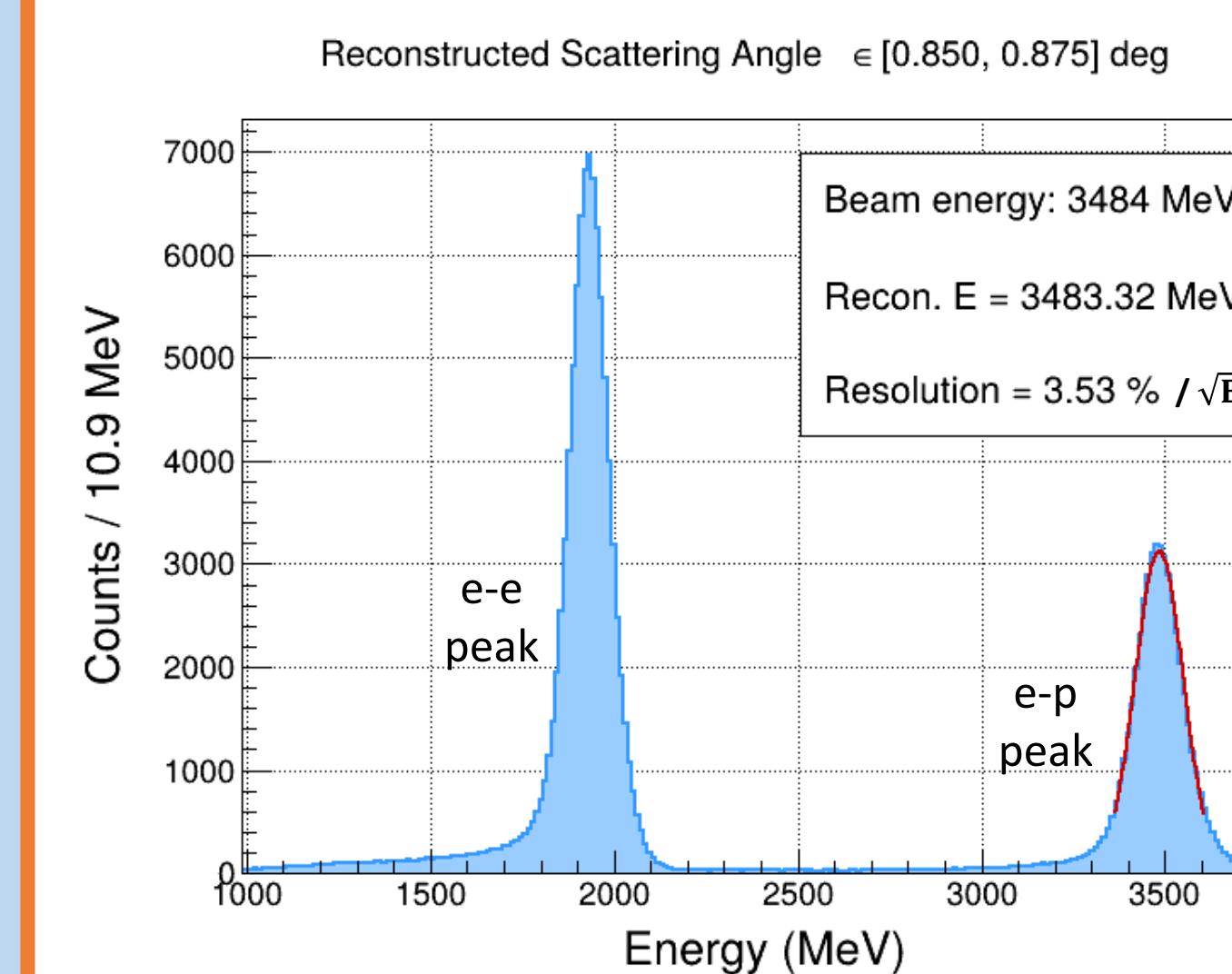
- Complete data-taking for 0.7GeV and 3.5GeV, the measured cross section match the expect value well.
- The statistical goal for the 2 settings is achieved successfully (0.4% for the last bin)
- Will complete the last 2.2GeV data-taking in 2 weeks



Preliminary Analysis

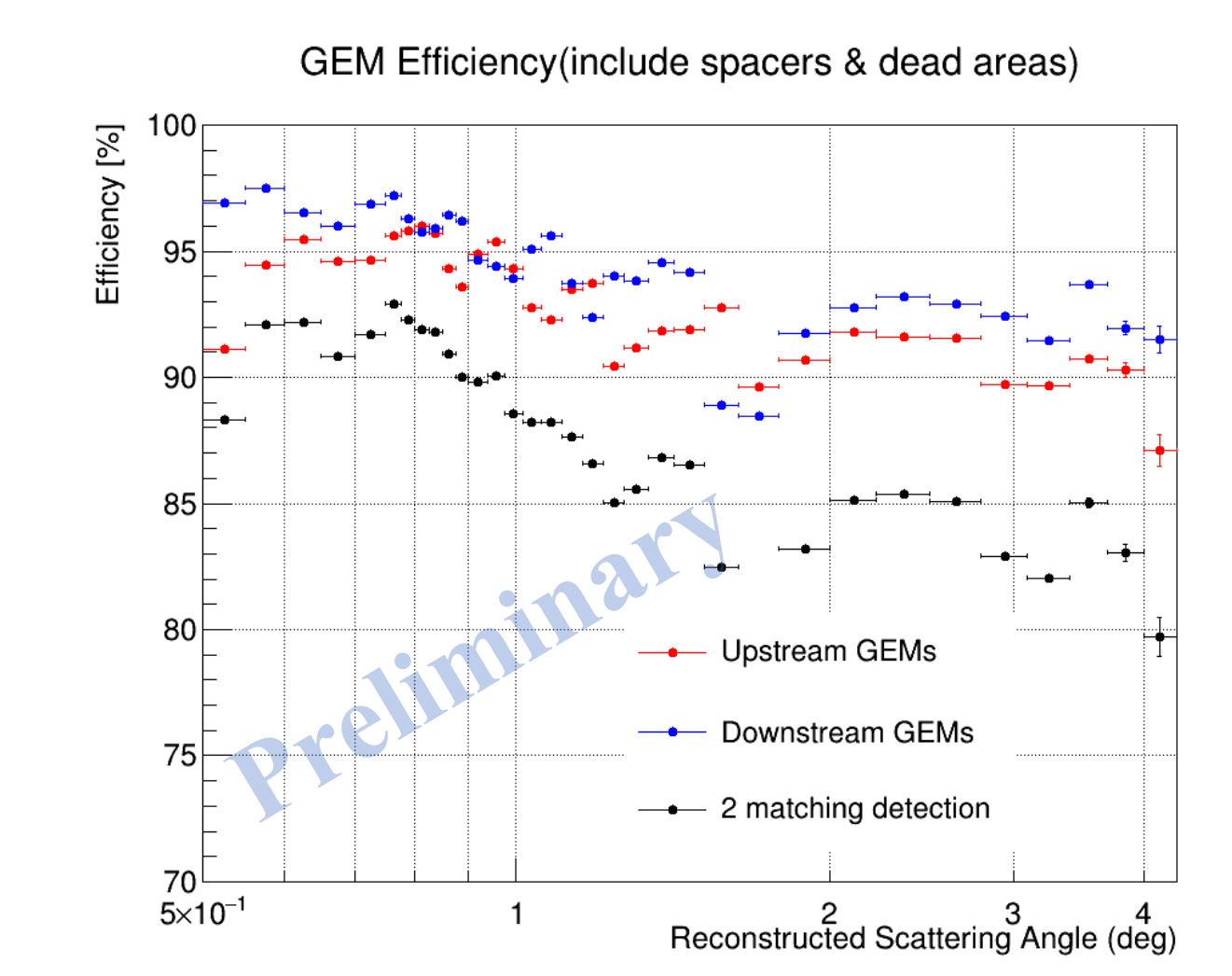
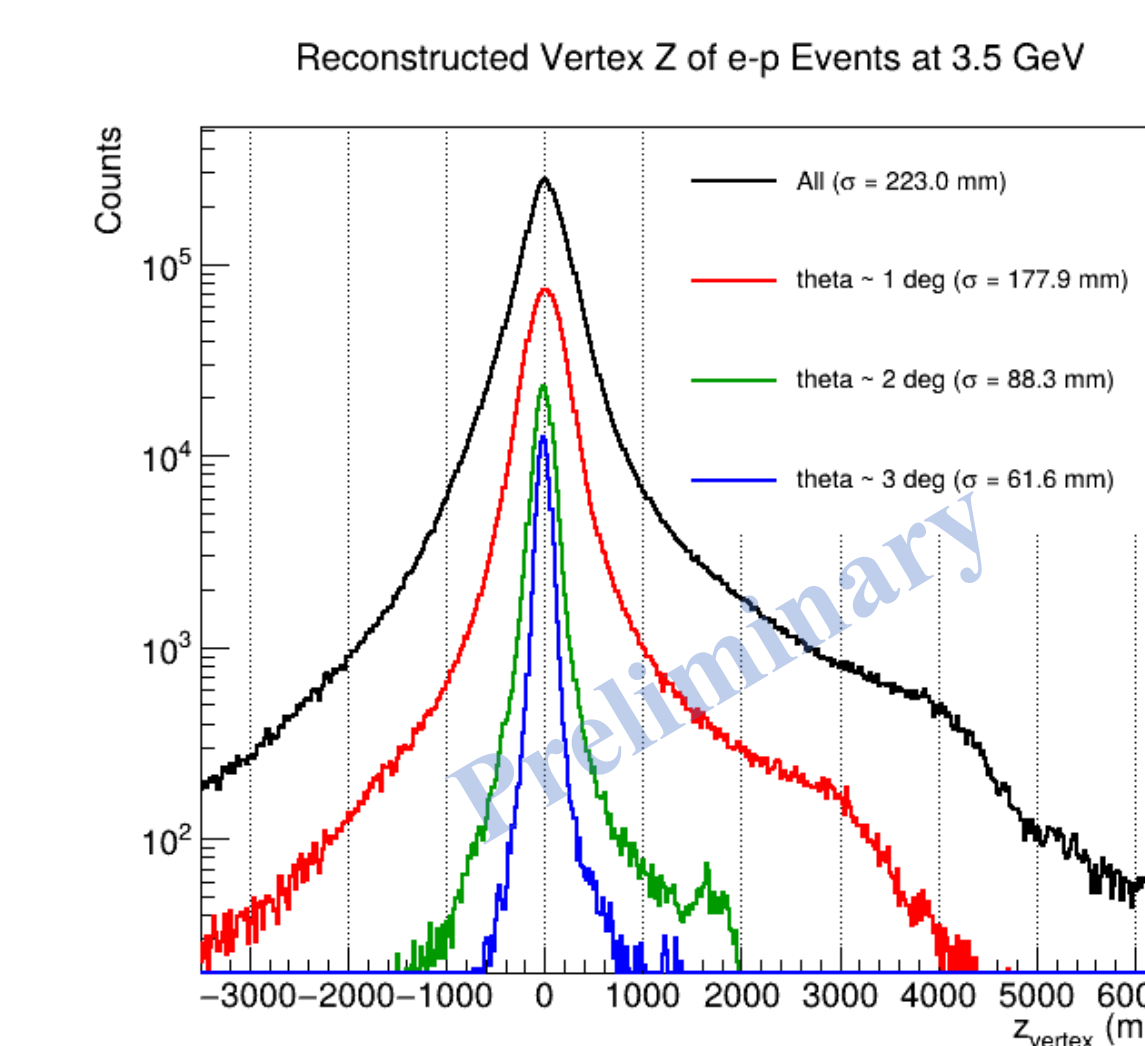
HyCal Reconstruction

- Complete initial energy calibration for HyCal
- Observe the nonuniformity pattern caused by flange of HyCal modules, a better resolution is promising after a correction



Performance of GEMs

- The reconstructed vertex resolution using 2 GEMs is as expected
- GEM efficiency is over 90%, detection efficiency requiring 2 layers matching is over 80%



Beam-Line Background Measurement

- Series of empty target configuration to study background sources and do background subtraction
- Major background source is the residual gas in/out target chamber
 - Thanks for a good beam profile, the major background in PRad (beam halo) nearly disappear

